

# **ELECTRONIC FUNDAMENTALS**

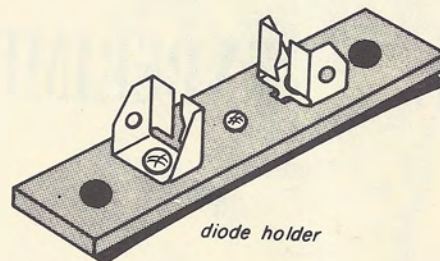
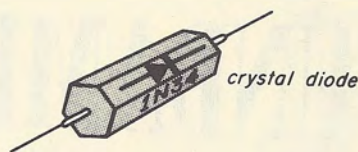
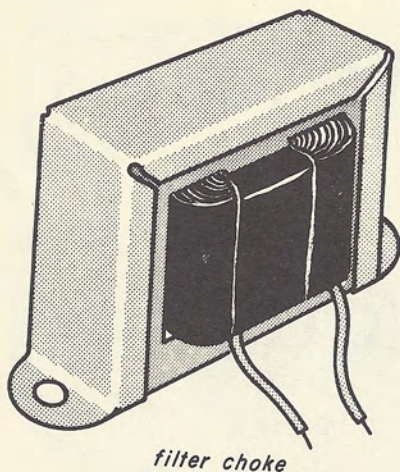
## **EXPERIMENT LESSON 11**

**CALCULATION OF METER MULTIPLIERS  
AND SHUNTS**



**RCA INSTITUTES, INC.**  
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**HOME STUDY SCHOOL**  
***350 West 4th Street, New York 14, N. Y.***





All the parts in Kit 6 are listed below. Check the parts you receive against this list. Make sure you have the correct quantity of every item. If a part is either missing or defective upon arrival, request a replacement from Department R, Home Study School, RCA Institutes, Inc., 350 West 4th Street, New York 14, N.Y. Your request must include your name and student number, the complete name and description of the part copied from the Item column below, the Quantity missing or defective, and the reason you are asking for a new part.

### KIT 6

### BILL OF MATERIALS

| Quantity | Item                                                 |
|----------|------------------------------------------------------|
| 2        | Crystal diodes                                       |
| 3        | Diode holders                                        |
| 1        | Capacitor, 0.01 $\mu$ f, paper, 1,600 volts, tubular |
| 1        | Choke, filter, 400 ohms, 8 h at 50 ma                |
| 1        | 6' line cord with male plug                          |
| 2        | Resistors, 10 megohms, $\frac{1}{2}$ watt, 10%       |
| 5'       | #20 solid wire                                       |



# Experiment Lesson 11

## OBJECT

To gain a better understanding of your multimeter by checking the calculations for the voltmeter, ammeter, and ohmmeter sections.

## INTRODUCTION

This is an unusual experiment lesson. In it, you will not find experiments of the usual type. Yet, it is one of the most important and valuable lessons in this course. Your multimeter, which you will complete in Experiment Lesson 13, is one of the most important tools you will ever use. It is not enough that you know how to use the meter to make certain measurements; you should know what each part in each meter circuit does and why it was selected.

In Theory Lesson 11, you learned the reasons for placing multipliers and shunts in your multimeter. You learned how to calculate the values of these multipliers and shunts. In the first part of this experiment lesson, you will use this knowledge to calculate the values of the multipliers and shunts used in your multimeter. By doing so, you will gain a better understanding of why these resistors are used in your meter. This understanding will help you to find trouble in your meter circuits.

**Note:** In making these calculations and others that will come up in the course, it is a good idea to use powers of ten. You remember that we discussed them in Theory Lesson 7. If you haven't been using them,

you would do well to get into the habit of doing so. If you need to brush up on the use of powers of ten, reread the part of Theory Lesson 7 that discusses how to use them. Of course, if you find some other method easier or more convenient to use, by all means use it.

If you master this easy-to-learn material, you will never find yourself in the position of the many radio and television servicemen who do not know enough about their meters to locate and repair troubles and who, therefore, must send their meters to a meter repair shop. Such servicemen lose money in two ways. They must miss calls because they do not have a meter and they must pay for the repairs that they could have made themselves if they had known all that you are going to learn about meters in this lesson.

## JOB 11-1

To calculate the resistance values of multipliers used in the d-c voltmeter section of your multimeter.

## EQUIPMENT NEEDED

Several sheets of unlined paper, 8½ x 11 inches

Pen or pencil

## Procedure.

Step 1. Draw a schematic symbol for a meter movement. Mark the inside of the circle 50  $\mu$ a, and under it write the meter re-



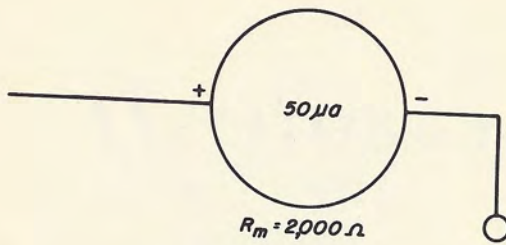


Fig. 11-1

sistance,  $R_m = 2,000$ . Draw a line from the negative side of the meter symbol to the negative meter jack. Your drawing should look like Fig. 11-1. Notice that the positive lead of the meter movement is not connected to a positive meter jack. As you calculate multiplier values, you will add resistors in series with this positive lead.

Step 2. Using the formula  $E = I_m \times R_m$ , calculate the voltage across the terminals of the meter you have drawn. Read no further until you have finished your calculations.

If your calculations are correct, you should have the following result:

$$\begin{aligned} E &= 0.00005 \times 2,000 \\ &= 5 \times 10^{-5} \times 2 \times 10^3 \\ &= 10 \times 10^{-2} \\ &= 0.1 \text{ volt} \end{aligned}$$

or

$$\begin{aligned} E &= 0.00005 \times 2,000 \\ &= 0.05 \times 2 \\ &= 0.1 \text{ volt} \end{aligned}$$

If your answer does not agree with the value given here, check your calculations to find out where you made a mistake. This is very important. REMEMBER — THE PURPOSE OF DOING THIS WORK IS NOT TO GET THE RIGHT ANSWERS ANY WAY THAT YOU CAN, BUT TO LEARN HOW TO CALCULATE CORRECTLY. The result of your calculations shows that the movement of

your meter can be used to measure voltages up to 0.1 volt. (When 0.1 volt is applied to your meter, the meter needle will be deflected full scale.) This is not a very useful limit to the range of your meter, so let us calculate the values of multipliers that will increase its range.

Step 3. Use the following formula in this step:

$$R_t = \frac{E}{I_m}$$

Calculate the total resistance that will be required in the circuit of your meter if you wish to use the meter to measure voltages up to 5 volts d.c. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following result:

$$\begin{aligned} R_t &= \frac{5}{5 \times 10^{-5}} \\ &= \frac{5 \times 10^5}{5} \\ &= 10^5 \\ &= 100,000 \text{ ohms} \end{aligned}$$

or:

$$\begin{aligned} R_t &= \frac{5}{0.00005} \\ &= 0.00005 \overline{)100,000} \\ &= 100,000 \text{ ohms} \end{aligned}$$

Step 4. To find the value of the multiplier required, subtract the resistance of the meter from  $R_t$ . Read no further until you have completed your calculations.

If your calculations are correct, you



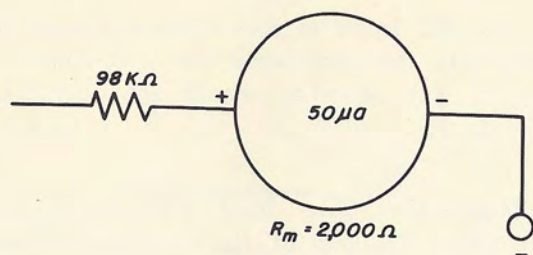


Fig. 11-2

should have the following result:

$$\begin{aligned} R_s &= 100,000 - 2,000 \\ &= 98,000 \text{ ohms} \end{aligned}$$

Therefore, the resistance value of the multiplier should be 98,000 ohms. Draw this resistor on your schematic diagram, as shown in Fig. 11-2.

Step 5. Calculate the value of the multiplier that must be added to the meter circuit shown in Fig. 11-2 so that the meter can be used to measure voltages up to 25 volts d.c. The procedure is the same as that described in Steps 3 and 4. Read no further until you have performed your calculations.

If your calculations are correct, you should have the following result:

$$\begin{aligned} R_t &= \frac{E}{I_m} \\ &= \frac{25}{5 \times 10^{-5}} \\ &= 5 \times 10^5 \\ &= 500,000 \text{ ohms} \end{aligned}$$

$$\begin{aligned} R_{25-v \text{ mult}} &= R_t - (R_m + R_{5-v \text{ mult}}) \\ &= 500,000 - (2,000 + 98,000) \\ &= 500,000 - 100,000 \\ &= 400,000 \text{ ohms} \end{aligned}$$

Step 6. Add the multiplier you chose in Step 5 to your schematic drawing. Your drawing should now look like Fig. 11-3.

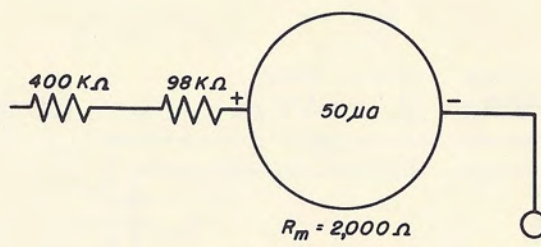


Fig. 11-3

Step 7. Calculate the value of the multiplier required to enable the meter shown in Fig. 11-3 to read 100 volts d.c. Once more, the procedure is the same as that described in Steps 3 and 4. Read no further until you have completed your calculation.

If your calculations are correct, you should have the following results:

$$\begin{aligned} R_t &= \frac{E}{I_m} \\ &= \frac{100}{5 \times 10^{-5}} \\ &= \frac{100 \times 10^5}{5} \\ &= \frac{10 \times 10^6}{5} \\ &= 2 \times 10^6 \\ &= 2 \text{ megohms} \end{aligned}$$

$$\begin{aligned} R_{100-v \text{ mult}} &= R_t - (R_m + R_{5-volt \text{ mult}} + R_{25-v \text{ mult}}) \\ &= 2,000,000 - (2,000 + 98,000 + 400,000) \\ &= 2,000,000 - 500,000 \\ &= 1,500,000 \text{ ohms} \end{aligned}$$

Step 8. Draw on your schematic a multiplier with the resistance value you calculated in Step 7. Your drawing should now



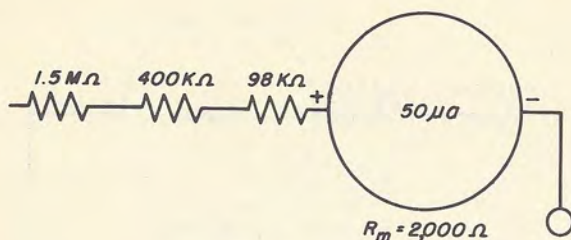


Fig. 11-4

look like Fig. 11-4.

Step 9. Calculate the value of resistance of a multiplier that will enable your multimeter to measure voltages up to 500 volts d.c. Use the same procedure you have used to calculate the other multipliers in your meter. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 R_t &= \frac{E}{I_m} \\
 &= \frac{500}{5 \times 10^{-5}} \\
 &= \frac{500 \times 10^5}{5} = \frac{5 \times 10^7}{5} \\
 &= 10^7 \\
 &= 10 \text{ megohms}
 \end{aligned}$$

$$\begin{aligned}
 R_{500\text{-v mult}} &= R_t - (R_m + R_{100\text{-v mult}} + R_{25\text{-v mult}} + R_{5\text{-v mult}}) \\
 &= 10,000,000 - (2,000 + 1,500,000 + 400,000 + 98,000) \\
 &= 10,000,000 - 2,000,000 \\
 &= 8,000,000 \text{ ohms}
 \end{aligned}$$

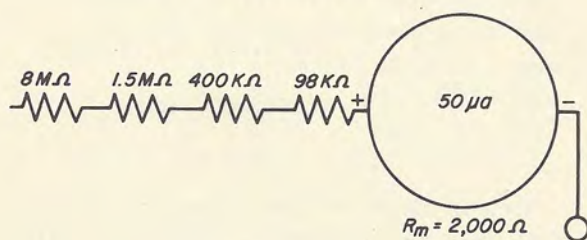


Fig. 11-5

Step 10. Draw on your schematic a multiplier with the resistance you calculated in Step 7. Your drawing should now look like Fig. 11-5.

**Discussion.** You have calculated the resistance values of the multipliers that are used in your meter. If you compare Fig. 11-5 with the schematic diagram of your multimeter shown in Fig. 11-6, you will see that the total resistance value of the multipliers used in both circuits is the same. However, you will note one difference; the circuit shown in Fig. 11-6 uses two resistors for the 98 k-ohm multiplier. The 98 k-ohm multiplier is so divided because of certain features of the ammeter section, which will be discussed later in this lesson.

Figure 11-6 shows the switch used to connect multipliers into the meter circuit. Another way of showing this switch (actually a simplified way of showing it) can be seen in Fig. 11-7. In the figure, the switch is in a position that connects the 98 k-ohm, 400 k-ohm, and 1.5-megohm multipliers into the circuit. With these multipliers in the circuit, the voltmeter section of your multimeter is set to the 100 VDC range. Moving the switch arm to the right cuts out multipliers and lowers the voltage range. For example, if the switch arm were moved so that it was between the 1.5 megohm multiplier and the 400-k ohm multiplier, the 1.5-megohm multiplier would be out of the voltmeter circuit and the switch would be in the 25 VDC position. Moving the switch to the left would add the 8-megohm multiplier to the circuit and, therefore, the switch would be in the 500 VDC position.

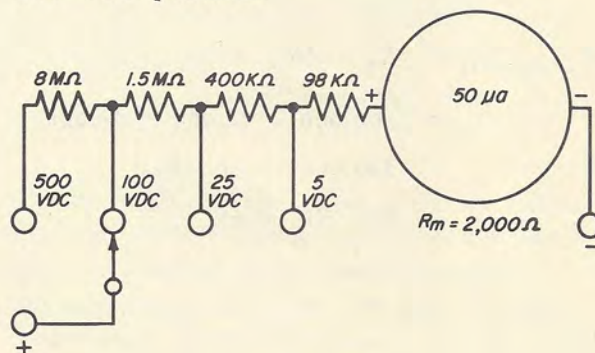


Fig. 11-7



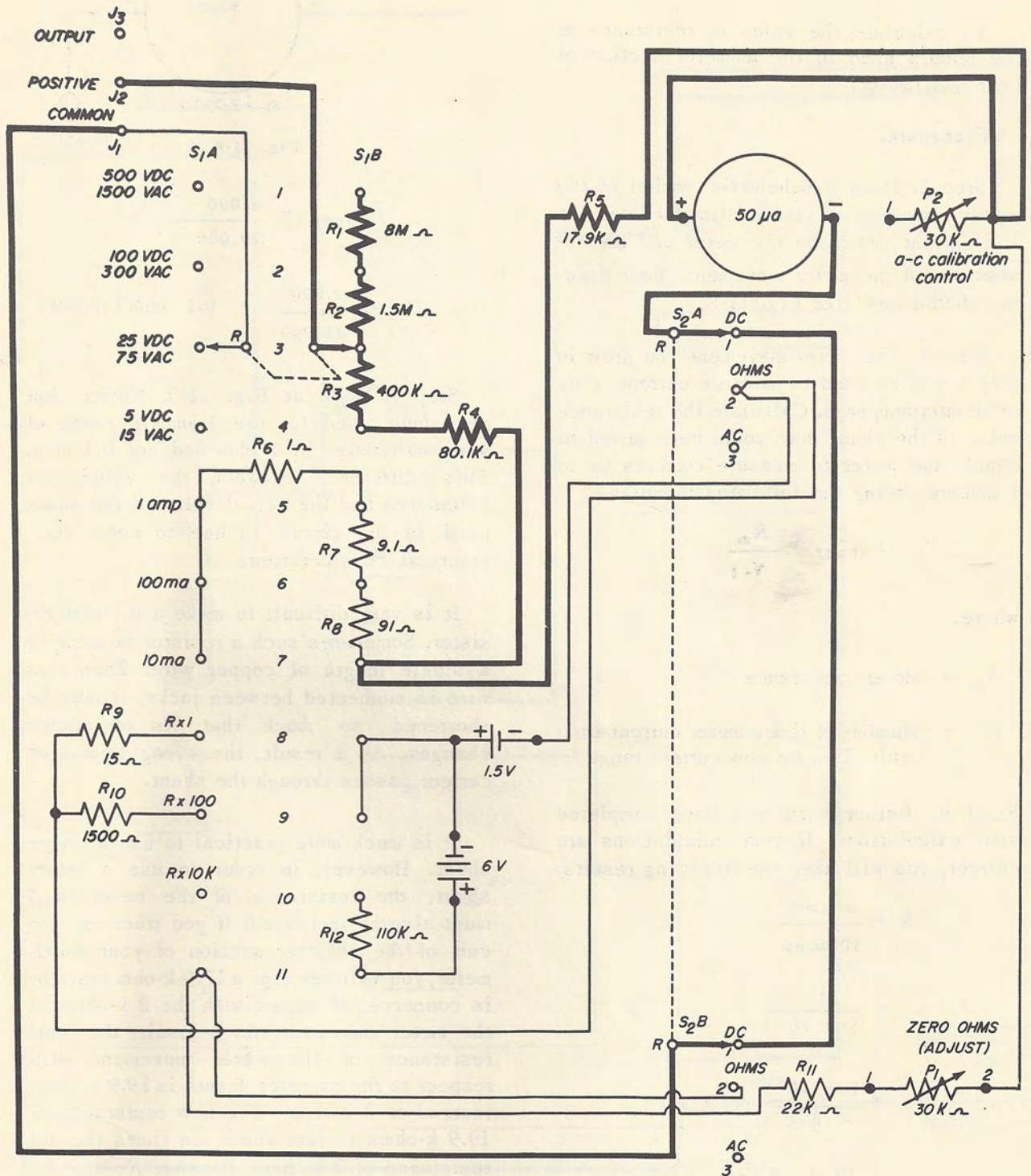


Fig. 11-6



## JOB 11-2

To calculate the value of resistance of the shunts used in the ammeter section of your multimeter.

**Procedure.**

Step 1. Draw a schematic symbol of the meter movement of your multimeter. Indicate the current drawn by the meter and the resistance of the meter movement. Your drawing should look like Fig. 11-8.

Step 2. The meter movement you drew in Step 1 can be used to measure current of up to 50 microamperes. Calculate the resistance value of the shunt that would be required to enable the meter to measure currents up to 1 ampere, using the following formula:

$$R_{\text{shunt}} = \frac{R_m}{N-1}$$

where:

$R_m$  = Meter resistance

$N$  = Number of times meter current is multiplied for new current range

Read no further until you have completed your calculations. If your calculations are correct, you will have the following results:

$$\begin{aligned} N &= \frac{1 \text{ amp}}{50 \text{ } \mu\text{amp}} \\ &= \frac{1}{5 \times 10^{-5}} \\ &= \frac{1 \times 10^5}{5} \\ &= \frac{10 \times 10^4}{5} \\ &= 2 \times 10^4 \\ &= 20,000 \end{aligned}$$

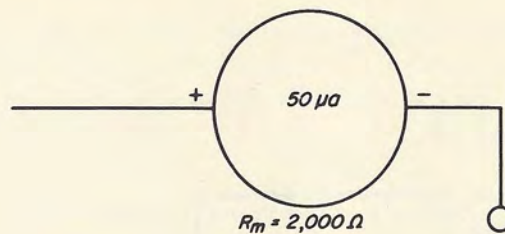


Fig. 11-8

$$\begin{aligned} R_{\text{shunt}} &= \frac{2,000}{20,000-1} \\ &= \frac{2,000}{19,999} = 0.1 \text{ ohm (approx)} \end{aligned}$$

Step 3. Look at Fig. 11-9. Notice that the shunt used for the 1-ampere range of your multimeter is 1 ohm and not 0.1 ohm. This difference between the value you calculated and the actual value of the shunt used in the circuit is due to some very practical considerations.

It is very difficult to make a 0.1-ohm resistor. Sometimes such a resistor is made of a single length of copper wire. When this wire is connected between jacks, it may be shortened so much that its resistance changes. As a result, the wrong amount of current passes through the shunt.

It is much more practical to use a larger shunt. However, in order to use a larger shunt, the resistance of the meter ( $R_m$ ) must also be increased. If you trace the circuit of the ammeter section of your multimeter, you will see that a 17.9-k-ohm resistor is connected in series with the 2 k-ohms of the meter movement. As a result, the total resistance of the meter movement with respect to the ammeter shunts is 19.9 k-ohms instead of 2 k-ohms. The new resistance of 19.9 k-ohms is just about ten times the old resistance of 2 k-ohms. Because  $R_7$  and  $R_8$  are small, they are neglected in our calculations for the sake of simplicity. Therefore, it is possible to use shunts that have a resistance value ten times greater than that of the shunts that can be used with a 2 k-ohm movement.



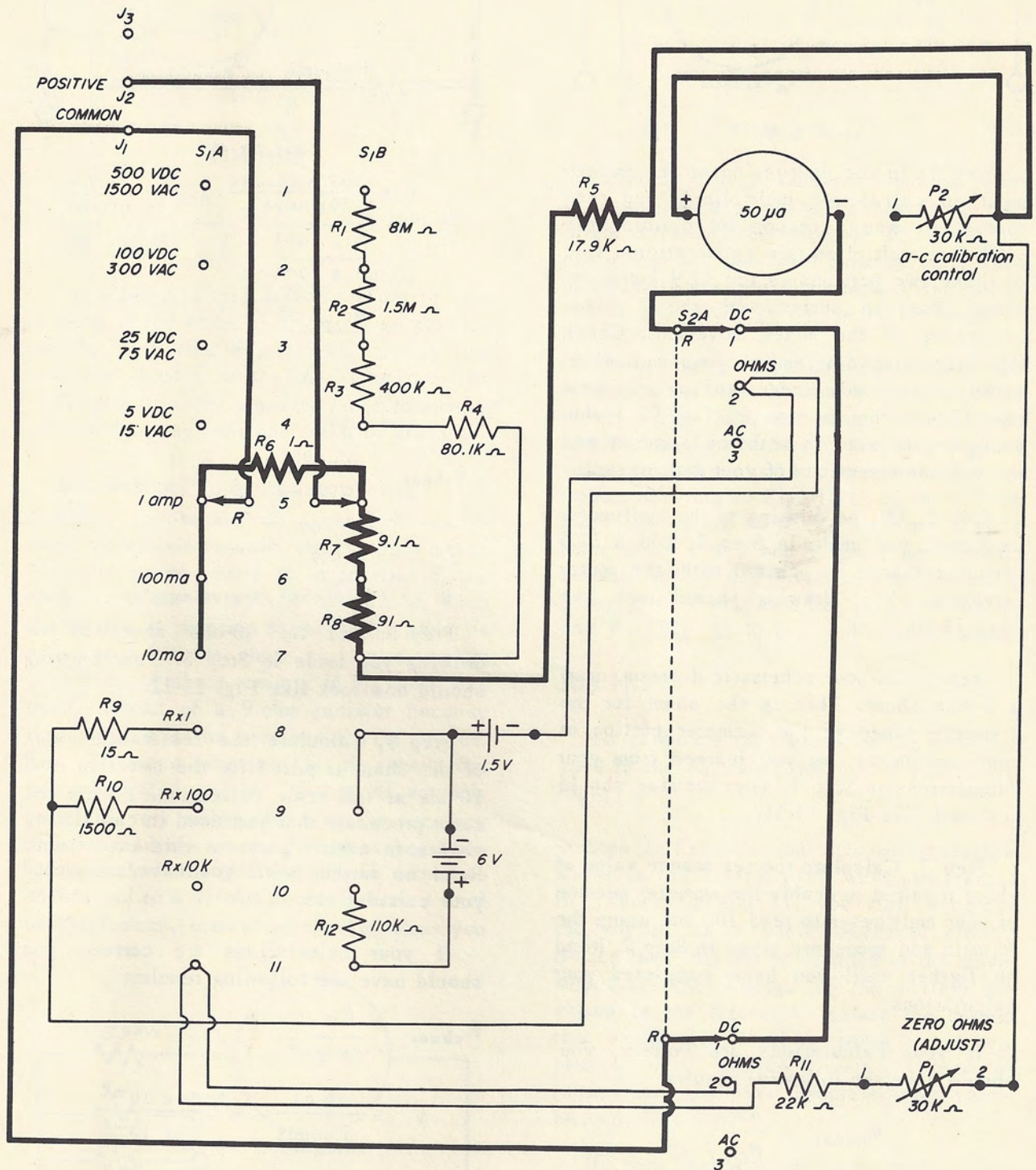


Fig. 11-9



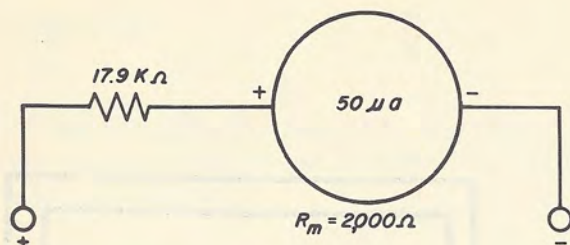


Fig. 11-10

Step 4. In the discussion of the experiment in calculating multipliers, you read that there was a reason for dividing the 98 k-ohm multiplier into two portions. One of these two portions is the 17.9 k-ohm resistor used in series with the 2 k-ohm resistance of the meter movement. Check the schematic diagram of your multimeter again so that you understand exactly how the 17.9 k-ohm portion of the 98 k-ohm multiplier is used in both the ammeter and the voltmeter sections of your multimeter.

Step 5. On the drawing of the multimeter movement you made in Step 1, add a 17.9 k-ohm resistor in series with the meter movement. Your drawing should look like Fig. 11-10.

Step 6. On your schematic diagram, draw a 1-ohm shunt. This is the shunt for the 1-ampere range of the ammeter portion of your multimeter, as you learned from your calculations in Step 1. Your drawing should now look like Fig. 11-11.

Step 7. Calculate the resistance value of shunt required to enable the ammeter section of your multimeter to read 100 ma, using the formula and procedure given in Step 2. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$R_{\text{shunt}} = \frac{R_m}{N-1}$$

where:

$$R_m = 17.9 \text{ k-ohms added to the resistance of the meter movement.}$$

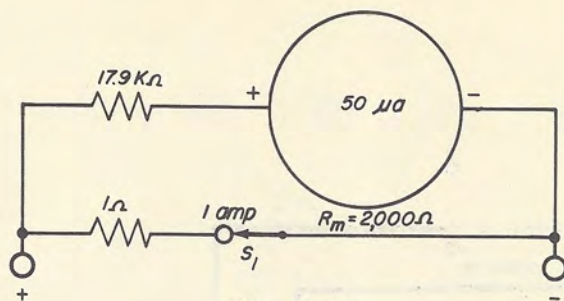


Fig. 11-11

$$N = \frac{100 \text{ milliamps}}{50 \mu\text{amps}} = \frac{0.1}{0.00005}$$

$$= \frac{1 \times 10^{-1}}{5 \times 10^{-5}} = \frac{1 \times 10^4}{5}$$

$$= \frac{10 \times 10^3}{5}$$

$$= 2 \times 10^3$$

$$= 2000$$

$$R_{\text{shunt}} = \frac{19,900}{2000 - 1}$$

$$= \frac{19,900}{1,999}$$

$$= 10 \text{ ohms (approximately)}$$

Step 8. Add the 10-ohm shunt to the drawing you made in Step 5. Your drawing should now look like Fig. 11-12.

Step 9. Calculate the resistance value of the shunt required for the meter to read 10 ma at full-scale deflection. Follow the same procedure that you used in calculating shunts in earlier parts of this experiment. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$R_{\text{shunt}} = \frac{R_m}{N-1}$$

$$N = \frac{0.01}{0.00005} = \frac{1 \times 10^{-2}}{5 \times 10^{-5}}$$

$$= \frac{1 \times 10^3}{5}$$

$$= 2 \times 10^2$$

$$= 200$$



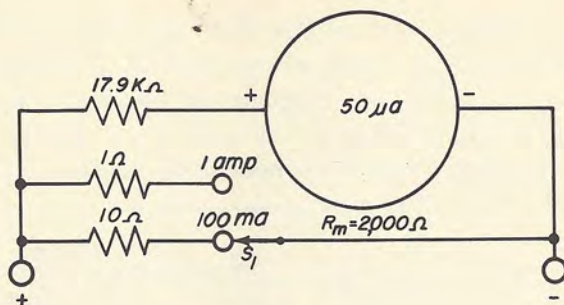


Fig. 11-12

$$R_{\text{shunt}} = \frac{19,900}{200 - 1} = \frac{19,900}{199} = 100 \text{ ohms}$$

Step 10. Add this 100-ohm shunt to your drawing of the ammeter circuit. Your drawing should look like Fig. 11-13. Notice that only one shunt is in the circuit at one time. Switching from one ammeter range to another means changing from one shunt to another.

**Discussion.** Look again at Fig. 11-9. Compare the values of shunts you calculated with those actually used in your meter. When the range switch is in position 5, the shunt is 1 ohm — as you calculated. When the switch is position 6, the 1-ohm shunt is added to a 9.1-ohm shunt, making a total of 10.1 ohms. A shunt resistor of 9.1 ohms was used instead of a 9-ohm resistor because this value was the standard RETMA value. The difference between the 10 ohms that you calculated and the 10.1 ohms actually used has very slight effect on the accuracy of your readings on the 100-ma range. When the switch is in position 7, the first two shunts add to a 91-ohm shunt, making a total of 101.1 ohms, instead of the 100 ohms you

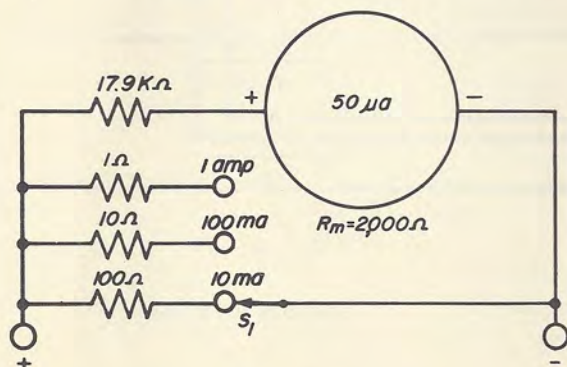


Fig. 11-13

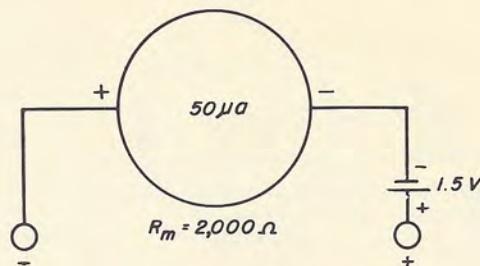


Fig. 11-14

calculated. The 91-ohm resistor was used because it is a standard RETMA value. The slight difference between the 100 ohms you calculated and the 101.1 ohms actually used makes only a slight difference in the accuracy of your readings on the 10-ma range.

Thus, the values calculated with the simple shunt formula can be translated to those of the Universal shunt formula. This can be done by subtracting any simple shunt value from the next higher value. For example, referring to Fig. 11-13 on the 100-ma range, the shunt should be 10 ohms; this is made up of 1 ohm and 9 ohms, which would be obtained by the Universal shunt formula. Thus, the 10-ohm resistor becomes the  $R_6$  and  $R_7$  (Fig. 11-9) in the Universal shunt.

### JOB 11-3

To calculate the values of the resistors used in the ohmmeter section of your multimeter.

Step 1. Examine the schematic diagram shown in Fig. 11-14. From what you learned in Theory Lesson 11, you may recognize the circuit as a basic ohmmeter circuit. Notice that only the resistance of the movement and the voltage of the battery are shown in the figure. Calculate the current that would flow in this circuit if the test probes were shorted together. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following result:

$$\begin{aligned} I &= \frac{1.5}{2 \times 10^3} = 0.75 \times 10^{-3} \\ &= 0.00075 = 750 \text{ } \mu\text{amps} \end{aligned}$$



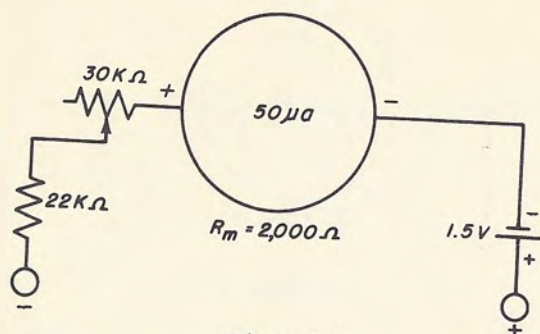


Fig. 11-15

Step 2. You know that the movement of your meter is rated at 50 microamperes. To limit the current flowing in the circuit to that value, a 22 k-ohm resistor and a 30 k-ohm rheostat have been inserted in the circuit, as shown in Fig. 11-15. To understand the function of these resistors, calculate the amount of resistance that is required in the circuit if the 1.5-volt cell is to produce a current flow of 50  $\mu$ amps in the circuit. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 R &= \frac{1.5}{50 \times 10^{-6}} && \frac{9}{10 \times 10^{-3}} \\
 &= \frac{1.5 \times 10^6}{50} && \frac{9 \times 10^3}{100} \\
 &= \frac{150 \times 10^4}{50} && \frac{900 \times 10^4}{100} \\
 &= 3 \times 10^4 && 9 \times 10^3 \\
 &= 30,000 \text{ ohms} && 90,000
 \end{aligned}$$

The resistance of the meter is 2,000 ohms. The resistance of the 22 k-ohm resistor added to the resistance of the meter gives a total of 24 k-ohms. According to your calculations, only 6 k-ohms more are required to maintain current at the proper level. The 30 k-ohm variable resistor (a potentiometer connected as a rheostat) will provide this 6 k-ohm resistance, or more resistance, or less resistance.

Step 3. Let us find out why a 30 k-ohm rheostat is used where one of 6 k-ohms seems sufficient. Suppose the voltage of the 1.5-volt cell should drop as low as 1.2 volts. Then the resistance necessary to limit the current to 50  $\mu$ a is:

$$\begin{aligned}
 R_s &= \frac{1.2}{0.00005} && \frac{7}{100 \times 10^{-3}} \\
 &= \frac{1.2}{5 \times 10^{-5}} && \frac{7}{10^{-3}} \\
 &= \frac{1.2 \times 10^5}{5} && 7 \times 10^3 \\
 &= \frac{12 \times 10^4}{5} \\
 &= 2.4 \times 10^4 \\
 &= 24,000 \text{ ohms} && 70,000
 \end{aligned}$$

A series resistance of 22,000 ohms added to the 2,000 ohms of the meter movement is the smallest value that we are likely to need.

Step 4. Now let us calculate the greatest value of resistance we are likely to need. Look at Fig. 11-16. It shows the ohmmeter section of your multimeter. When the range switch is in the  $R \times 10K$  position, there is a total of 7.5 volts used in the ohmmeter circuit. The series resistance necessary to limit the current to 50  $\mu$ a is:

$$\begin{aligned}
 R_s &= \frac{7.5}{0.00005} && \frac{10}{10001} \\
 &= \frac{7.5}{5 \times 10^{-5}} \\
 &= \frac{7.5 \times 10^5}{5} \\
 &= 1.5 \times 10^5 \\
 &= 150,000 \text{ ohms}
 \end{aligned}$$

In series with the battery voltage we have  $R_{12}$  (110 k-ohms),  $R_{11}$  (22 k-ohms), and



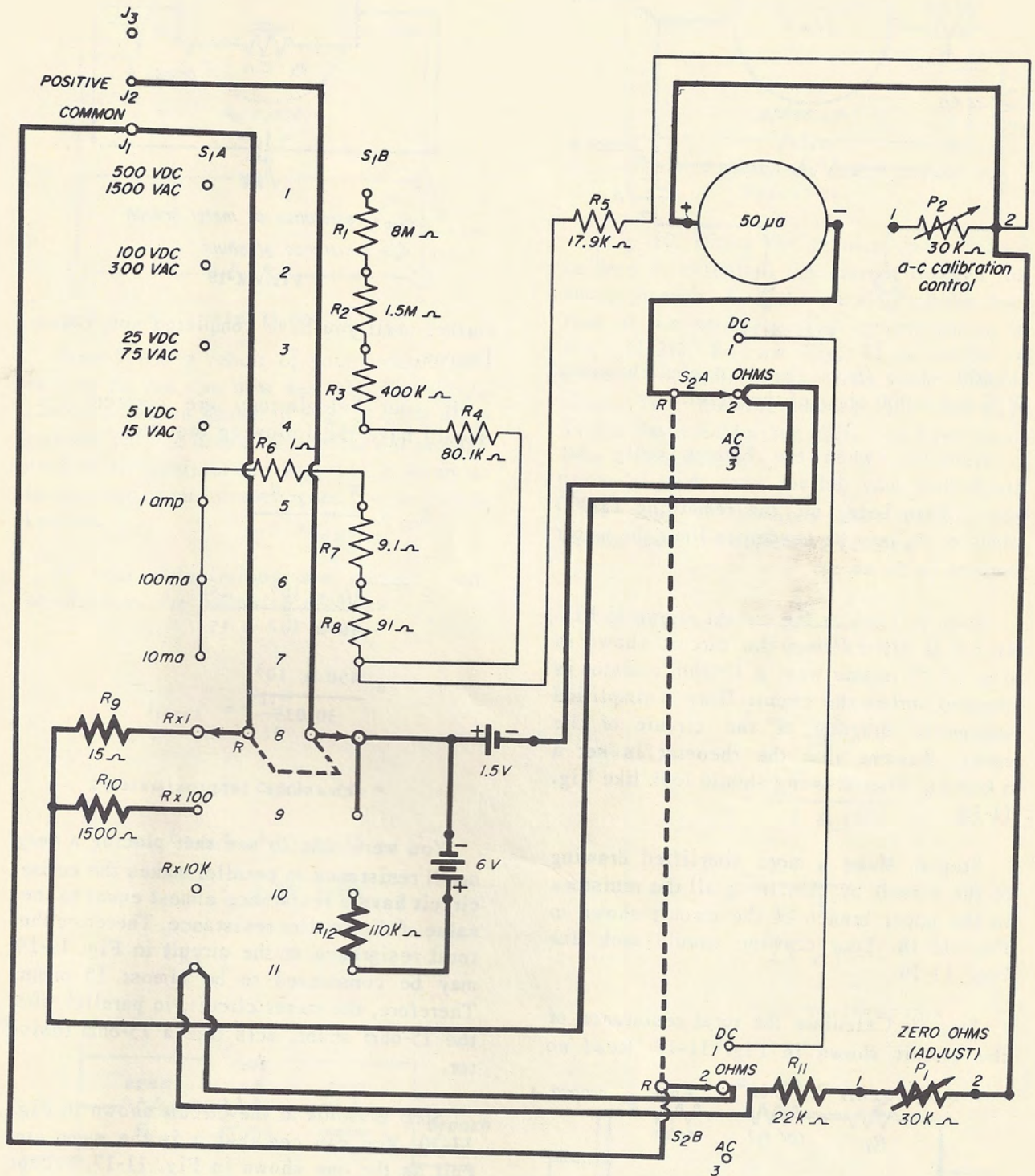


Fig. 11-16



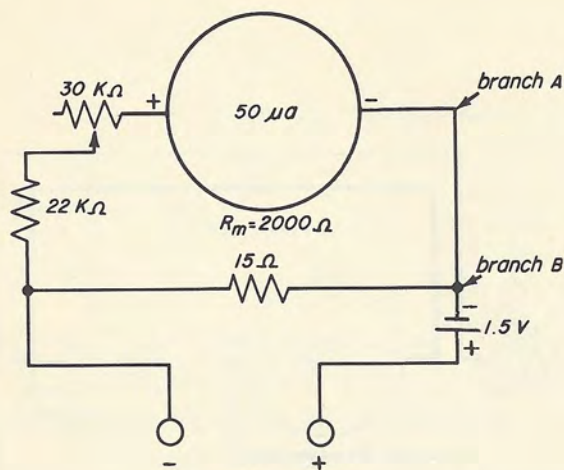


Fig. 11-17

16,000 ohms (from the 30 k-ohm rheostat,  $P_1$ ), and 2,000 ohms of the meter.

However, when the battery cells are fresh they may deliver more than 1.5 volts each. This being so, the remaining 12,000 ohms of  $P_1$  may be needed to limit the meter current to 50  $\mu$ a.

Step 5. Look at the circuit shown in Fig. 11-17. It differs from the circuit shown in Fig. 11-15 in one way; a 15-ohm resistor is shunted across the circuit. Draw a simplified schematic diagram of the circuit of the meter. Assume that the rheostat is set at 6 k-ohms. Your drawing should look like Fig. 11-18.

Step 6. Make a more simplified drawing of the circuit by combining all the resistors in the upper branch of the circuit shown in Fig. 11-18. Your drawing should look like Fig. 11-19.

Step 7. Calculate the total resistance of the circuit shown in Fig. 11-19. Read no

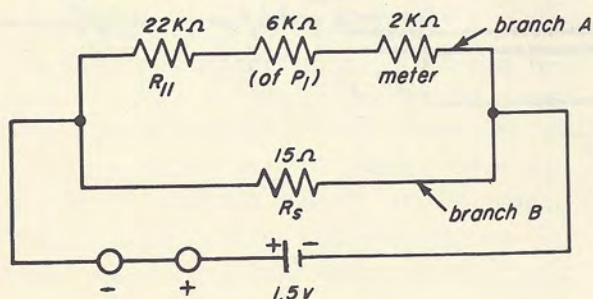
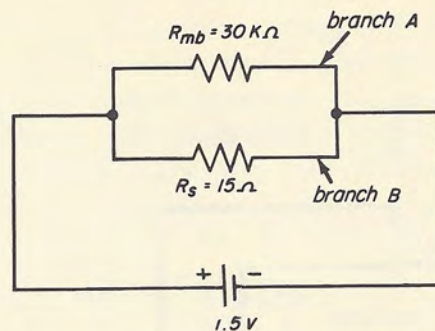


Fig. 11-18



$R_{mb}$  = resistance of meter branch

$R_s$  = resistance of shunt

Fig. 11-19

further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$R_t = \frac{R_{mb} \times R_s}{R_{mb} + R_s}$$

$$= \frac{30 \times 10^3 \times 15}{30 \times 10^3 + 15}$$

$$= \frac{450 \times 10^3}{30,015}$$

$$= 15 \text{ ohms (approximately)}$$

You were able to see that placing a very small resistance in parallel makes the entire circuit have a resistance almost equal to the value of the smaller resistance. Therefore the total resistance of the circuit in Fig. 11-19 may be considered to be almost 15 ohms. Therefore, the meter circuit, in parallel with the 15-ohm shunt, acts like a 15-ohm resistor.

Step 8. Look at the circuit shown in Fig. 11-20. You can see that it is the same circuit as the one shown in Fig. 11-17, except that a 15-ohm resistor is connected across terminals A and B of the meter. Draw a simplified circuit of the meter circuit shown in Fig. 11-20. Assume that the 30 k-ohm rheostat is set at 6 k-ohms. Your drawing should look like Fig. 11-21.



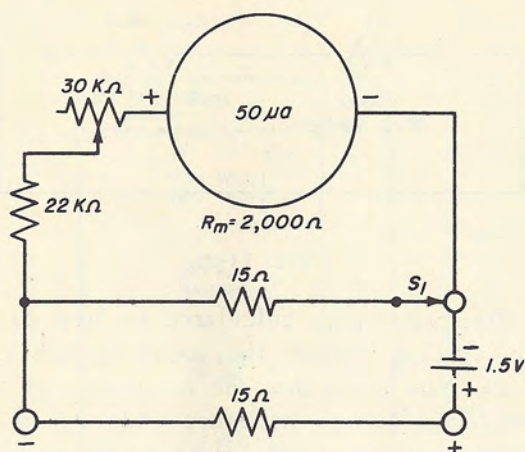


Fig. 11-20

Step 9. As a result of your calculations in Step 6, you can now see why Fig. 11-21 can be drawn as shown in Fig. 11-22. Calculate the voltage drops and the current through each of the resistors in Fig. 11-22. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 I_{\text{total}} &= \frac{1.5}{30} \\
 &= 0.05 \text{ amps} \\
 E_{R_{mc}} &= 0.05 \times 15 \\
 &= 0.75 \text{ volts} \\
 E_{R_x} &= 0.05 \times 15 \\
 &= 0.75 \text{ volts}
 \end{aligned}$$

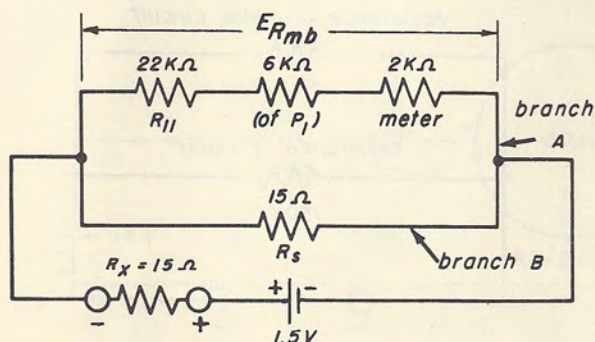


Fig. 11-21

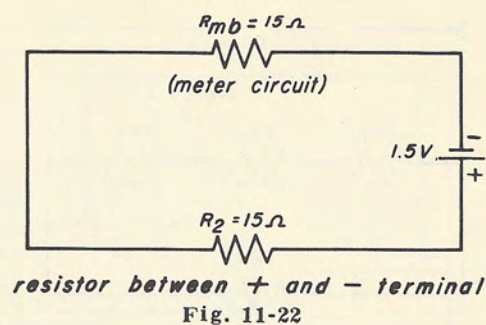


Fig. 11-22

Step 10. Using the results you obtained in Step 9, calculate the current through the meter (branch A of the parallel circuit portion of the series-parallel circuit shown in Fig. 11-21). Redraw Fig. 11-21 so as to make it easier for you to make your calculations. Your drawing should look like Fig. 11-23. Read no further until you have made your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 I_{\text{Branch A}} &= \frac{0.75}{30 \times 10^3} \\
 &= \frac{0.75 \times 10^{-3}}{30} \\
 &= \frac{7.5 \times 10^{-4}}{3 \times 10^1} \\
 &= \frac{7.5 \times 10^{-5}}{3} \\
 &= 2.5 \times 10^{-5} \\
 &= 25 \text{ microamperes}
 \end{aligned}$$

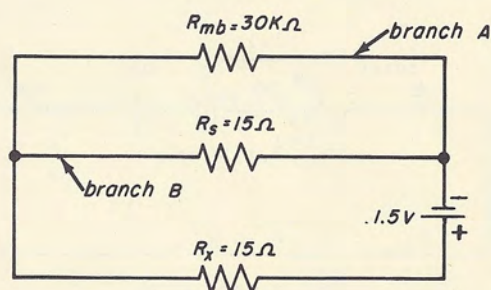


Fig. 11-23



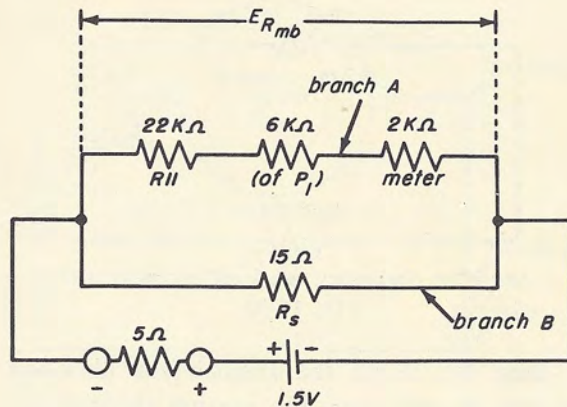


Fig. 11-24

The current going through Branch A is the current that goes through your meter circuit when your meter is connected with the 15-ohm shunt across it and the test leads are applied to a 15-ohm resistor. So, when the needle is in the 25- $\mu$ a position, it also points to the 15-ohm calibration on the ohms scale.

Step 11. Let us calculate what would happen if the test prods of the meter were connected across a 5-ohm resistor instead of across a 15-ohm resistor, as shown in Fig. 11-24. Figure 11-25 shows the simplified circuit. Using the same method as in Step 9, calculate the voltage across the meter branch and shunt, and the current flowing through the meter. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 I_{\text{total}} &= \frac{1.5}{20} \\
 &= 0.075 \text{ amp} \\
 E_{\text{Rmc}} &= I \times R \\
 &= 0.075 \times 15 \\
 &= 1.125 \text{ volts}
 \end{aligned}$$

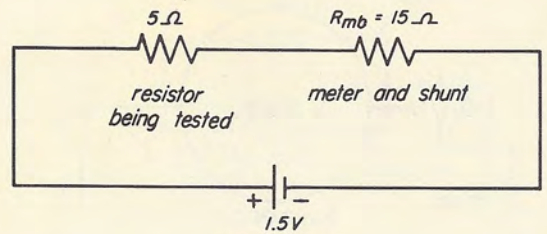


Fig. 11-25

Step 12.  $E_{\text{Rmc}}$  calculated in Step 11 is the voltage across the meter branch and shunt. You know that the resistance of the meter and series resistors adds up to 30 k-ohms, so you can calculate the current flowing through the meter. Read no further until you have completed your calculations.

If your calculations are correct, you should have the following results:

$$\begin{aligned}
 I_{\text{meter}} &= \frac{1.125}{3 \times 10^4} \\
 &= \frac{1.125 \times 10^{-4}}{3} \\
 &= 0.0000375 \\
 &= 37.5 \text{ } \mu\text{amps}
 \end{aligned}$$

The ohmmeter circuit discussed so far uses a 15-ohm shunt resistor. With this shunt resistor in the circuit of your multi-meter, the range switch is in the Rx1 position. As you learned in Service Practices 7, the most accurate resistance readings are obtained when the resistance being measured

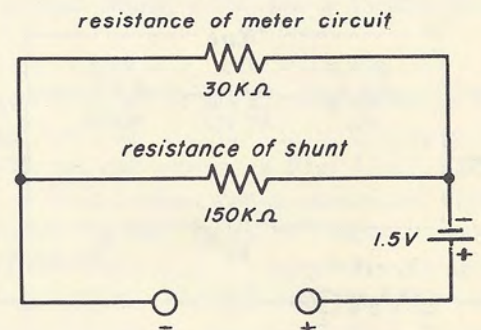


Fig. 11-26



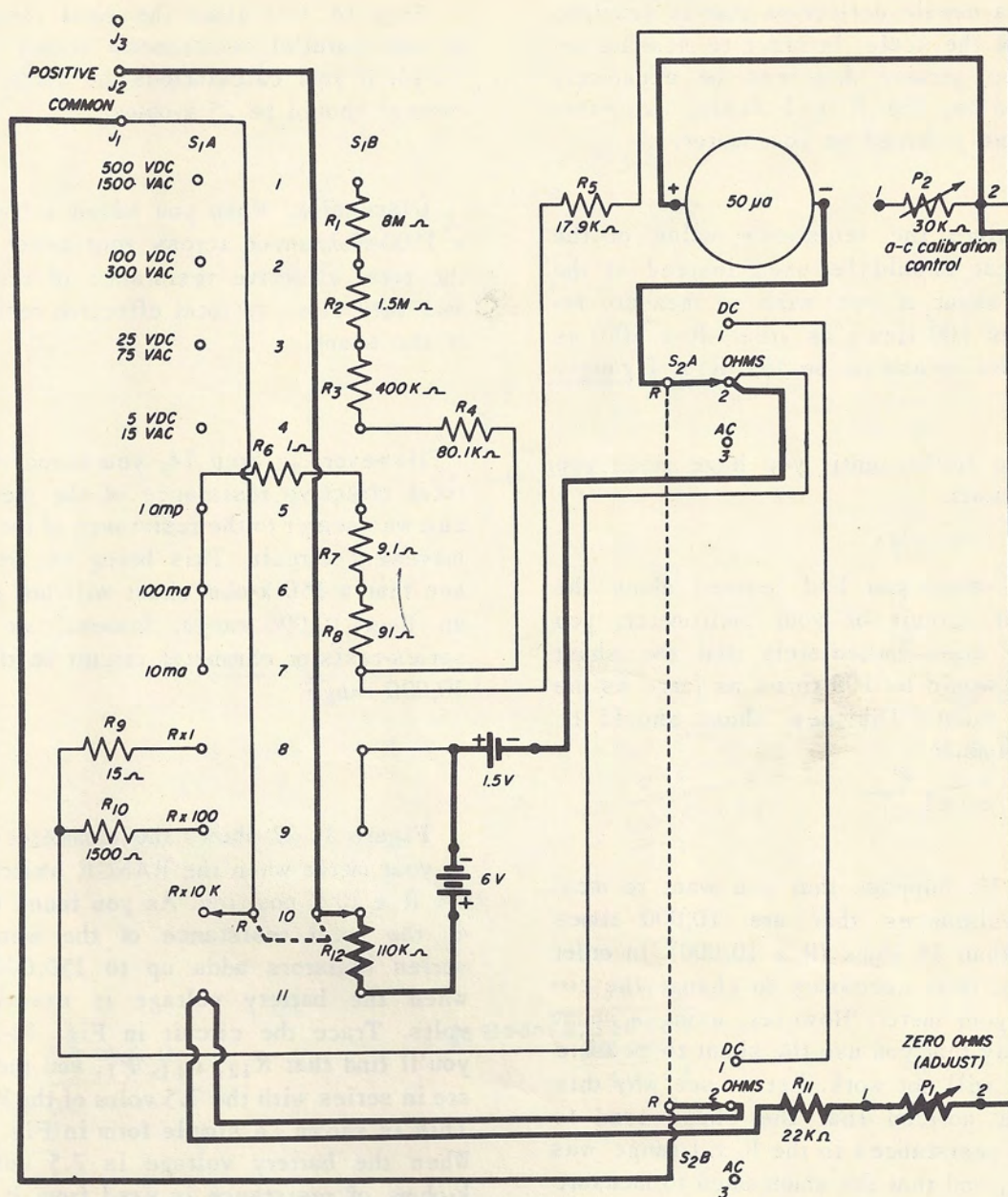


Fig. 11-27

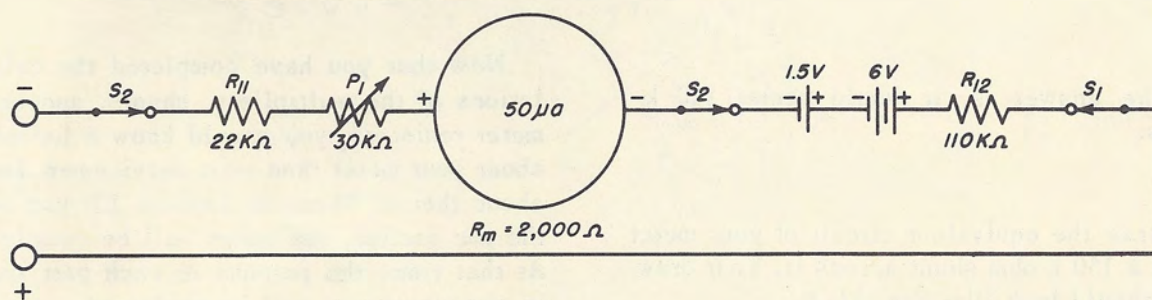


Fig. 11-28



causes a needle deflection that is near the center of the scale. In order to measure resistances greater than can be accurately measured on the  $R \times 1$  scale, two other scales are provided on your meter.

Calculate the resistance value of the shunt that should be used instead of the 15-ohm shunt if you wish to measure resistances 100 times as great ( $R \times 100$ ) as those you measured on the  $R \times 1$  range.

Read no further until you have made your calculations.

From what you had learned about the ohmmeter circuit of your multimeter, you probably knew immediately that the shunt required would be 100 times as large as the 15-ohm shunt. The new shunt should be 1,500 ohms.

Step 13. Suppose that you want to measure resistances that are 10,000 times greater than 15 ohms ( $R \times 10,000$ ). In order to do so, it is necessary to change the circuit of your meter. However, using a shunt in the way that you use the shunt to measure 15 ohms will not work. Let us see why this so. You noticed that the shunt used to measure resistances in the  $R \times 1$  range was 15 ohms, and that the shunt used to measure resistances in the  $R \times 100$  range was 1,500 ohms. Calculate the shunt required to measure 150 k-ohms.

The answer is, it would seem, 150 k-ohms.

Draw the equivalent circuit of your meter with a 150 k-ohm shunt across it. Your drawing should look like Fig. 11-26.

Step 14. Calculate the total resistance of the parallel resistances shown in Fig. 11-26. If your calculations are correct, your answer should be 25 k-ohms.

**Discussion.** When you added a 15-ohm or a 1500-ohm shunt across your meter circuit the total effective resistance of the meter was very close to total effective resistance of the shunt.

However, in Step 14, you found that the total effective resistance of the meter circuit was nearer to the resistance of the meter-movement circuit. This being so, you can see that a 150 k-ohm shunt will not give us an  $R \times 10,000$  range. Instead, we use a series-resistor ohmmeter circuit in the  $R \times 10,000$  range.

Figure 11-27 shows the ohmmeter circuit of your meter when the RANGE switch is in the  $R \times 10 K$  position. As you found in Step 4, the total resistance of the meter and series resistors adds up to 150,000 ohms when the battery voltage is exactly 7.5 volts. Trace the circuit in Fig. 11-27 and you'll find that  $R_{12}$ ,  $R_{11}$ ,  $P_1$ , and the meter are in series with the 7.5 volts of the battery. This is shown in simple form in Fig. 11-28. When the battery voltage is 7.5 volts, 16 k-ohms of resistance is used from  $P_1$ , and, as the voltage drops down, an even smaller amount of resistance will be needed to limit the meter current to  $50 \mu a$ .

Now that you have completed the calculations of the multipliers, shunts, and ohmmeter resistors, you should know a lot more about your meter than most servicemen know about theirs. When, in Lesson 12 you add the a-c portion, the meter will be complete. At that time, the purpose of each part used in measuring a.c. will be explained.